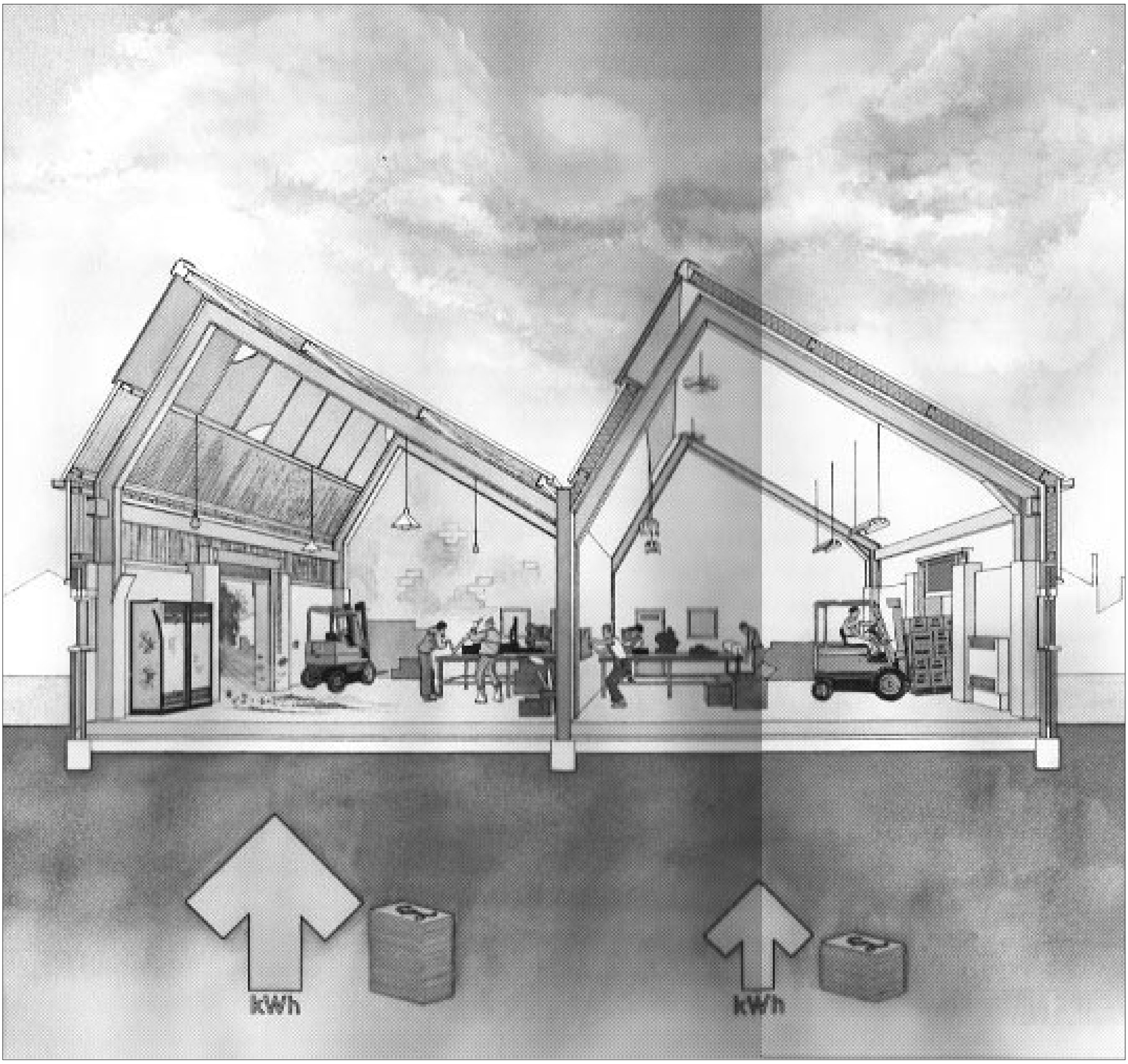
Guide 18

Energy Efficiency in Industrial Buildings and Sites



"Energy costs for energy efficient buildings and services can be 30-50% below average levels – sometimes more"

BEST PRACTICE PROGRAMME
ENERGY EFFICIENCY

INTRODUCTION AND OVERVIEW

Opportunities for reducing energy consumption, CO_2 emissions, and costs exist in almost all industrial buildings. Energy is a controllable overhead cost; savings go directly to increase profit and improve competitiveness. In addition, reducing energy use brings environmental benefits which will meet growing public concern and increasing environmental legislation. Energy generated from fossil fuels results in emissions, including CO_2. Efficient use of energy is seen as crucial to reducing the threat of global warming.

This Guide will help managers and staff to assess their energy use and identify ways in which cost-effective savings may be made. It will also be useful in discussions about energy use amongst technical staff, consultants, and managers.

Energy consumption and cost per unit area in industrial buildings varies greatly amongst different industries, buildings, and sites, and is dependent on fuel type, industrial process, and end uses. This Guide considers energy use at an industrial site from the following viewpoints:

- industry sector
- fuel type
- representative building types
- individual building services and opportunities for reducing energy consumption
- other influences including occupancy, weather, process effects.

Although the Guide concentrates on building services energy use, it is often difficult to separate process energy use unambiguously. Separate metering of industrial process energy from building services energy is desirable, but not often present. Moreover, the distinction is sometimes unclear. For example, energy used to provide compressed air may be attributed to building services or to process (process is assumed in this Guide). A ventilation system may be regarded as a building service or as essential to the process. The final destination of heat from the boiler may be difficult to identify.

Much of the information in this Guide comes from analysis of energy surveys (from the EEO's Energy Efficiency Survey Scheme) and Case Studies. Sites with similar patterns of activity and energy use are grouped under generic titles such as General Manufacturing (these broadly follow the Standard Industrial Classification (SIC)).[1]

[1] Standard Industrial Classification Revised 1980. CSO. HMSO 1980.

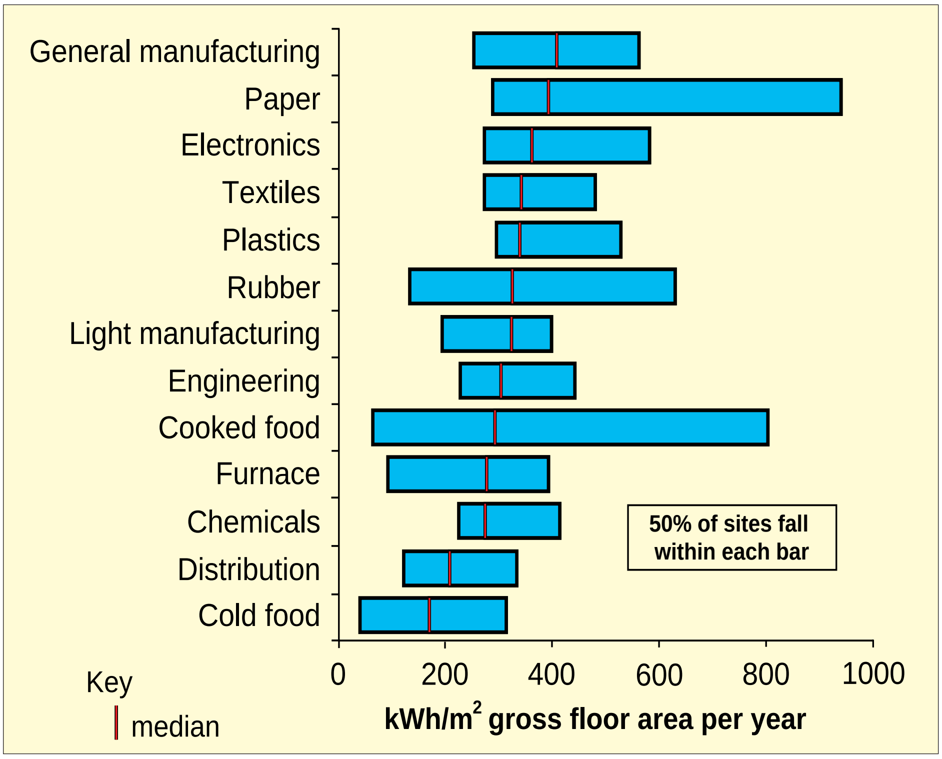


Figure 1 Buildings-related energy use

SCOPE FOR SAVINGS

Energy costs for energy efficient buildings and services can be 30-50% below average levels, sometimes more. This can give significant savings in overhead costs, depending on energy costs as a proportion of overheads. Some older sites have halved heating and lighting costs and made worthwhile savings elsewhere, without detriment to internal conditions, staff satisfaction, or product quality. Indeed, energy-efficient buildings are often better in these respects, since efficient use of energy is an indicator of good design and management generally.

The actions that can be taken are both technical and managerial. Some measures are easy to implement and pay for themselves rapidly. Others have significant costs of access or disruption, making them most cost-effective when part of new construction, refurbishment, alteration or maintenance. In new buildings, many energy saving features can be incorporated at the design stage at little or no extra cost. Good current practice in new, altered and refurbished buildings, in industrial processes and in energy management are illustrated in the Best Practice programme publications referred to at the end of this document.

RANGE OF ENERGY USE

Figure 1 shows the range of building-related energy consumption within industry sectors, and the differences amongst them. **In most sectors the highest 10% of sites consume well over twice the typical level, while the lowest 10% use half or less.** Some of this variation is legitimately related to different functions, processes and equipment, and to different intensities of use of the site. Nevertheless, there is often waste which can be avoided.

Carbon dioxide emissions

Carbon dioxide (CO_2) is a major contributor to the greenhouse effect and global warming. The Government is committed to reducing UK CO_2 emissions. Each kWh of energy used generates CO_2 in fuel extraction, processing and delivery, and in combustion at power stations or on site. A chart of CO_2 emissions would look similar to the chart of energy costs in figure 3 since CO_2 emissions per unit of fuel are similar to energy cost per unit of fuel. CO_2 emissions per unit of fuel depend on the fuel source, electricity generating mix, and other assumptions. Current values in kg CO_2 per kWh of delivered fuel are: Gas 0.21, Oil 0.29, Coal 0.32, Electricity 0.72. The value for electricity depends on the power generation mix and is decreasing with improving power station efficiencies and input fuel mixes. The value for on-site combined heat and power (CHP) generation can be very much lower.

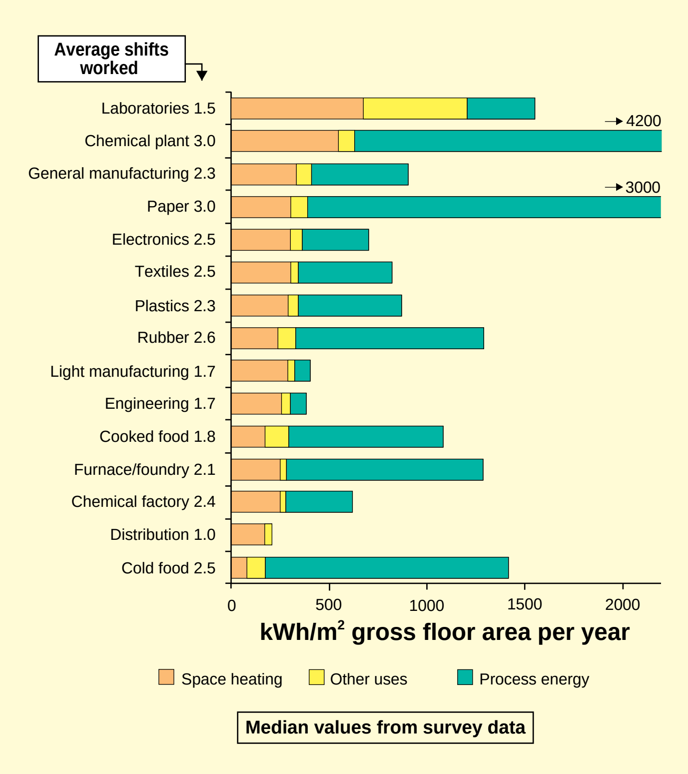


Figure 2 Total delivered energy consumption (data on p.10)

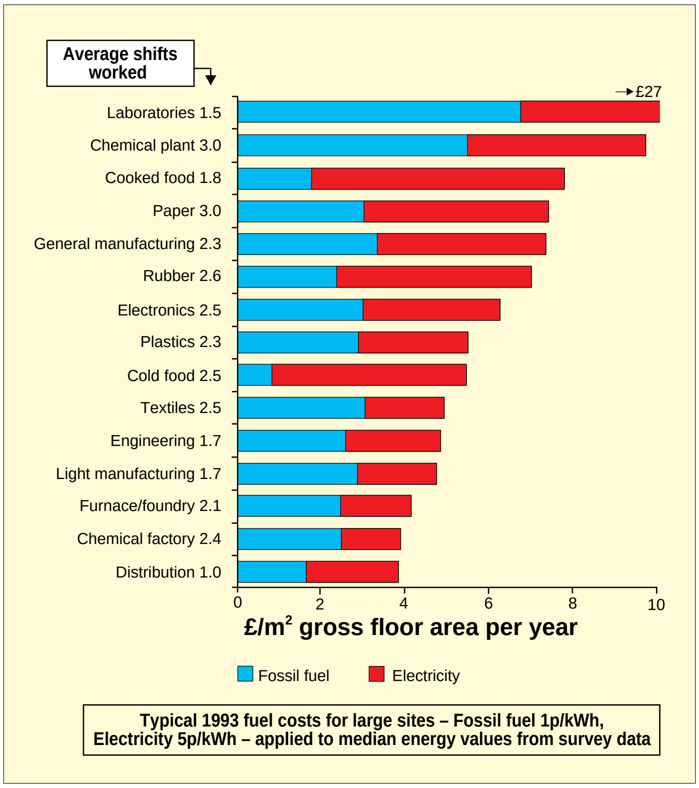


Figure 3 Buildings-related energy costs (data on p.10)

CONSUMPTION AND INDUSTRY SECTOR

Figure 2 shows typical (median) levels of annual delivered energy consumption for different types of industry (ordered by building-related energy consumption). 'Other uses' is mostly building-related electricity. Information on energy units and conversion factors is given in the box on page 6.

Only in light manufacturing, engineering, distribution and laboratories, is well over half the energy consumption building-related. Process fuel use varies with the process, with older industries and technologies tending to use large amounts of fossil fuel and newer ones using less fossil fuel and more electricity. Building energy consumption is usually dominated by fossil fuel (gas, oil or solid) for space heating. The relationships between process and building energy use are discussed later.

BUILDING-RELATED FUEL COSTS

Variations in fuel mix and supply contract for different industries and sites make direct comparison of energy costs difficult. Figure 3 uses standardised unit costs of 5 p/kWh of electricity and 1 p/kWh for fossil fuel: these were typical in 1993 for large sites. Costs for smaller sites and individual buildings may be considerably greater – see 'Typical fuel costs' box (page 3).

Although fossil fuel usually dominates building services' delivered energy use, the higher price of electricity makes annual costs of the two fuel types similar, as can be seen in figure 3. Compared with figure 2, the ranking order only changes significantly for Cold Food and Cooked Food, both relatively high electricity users.

REPRESENTATIVE BUILDING TYPES

Energy consumption (figure 4) and cost breakdowns (figure 5) are shown for four representative types.

The breakdowns are for buildings of 2000 m² or more in which most of the energy cost is attributable to building services. Fabric insulation typically averages around 1.5 W/m²K but this can vary from up to 6 W/m²K in completely uninsulated sheet metal sheds to 0.45 W/m²K or less in recent Good Practice construction.

Storage and distribution buildings

- Warehousing with typically 7.5 m clear internal height, and with pallet racking.
- Natural ventilation and warm air heating to 16°C for single shift operation during the day, with condensation protection at night.
- Lighting generally to 150 lux by high pressure sodium high bay fittings, with higher levels locally in dispatch and office areas.
- Average 10% rooflights.
- Excludes refrigerated warehousing.

Light manufacturing buildings

- Industrial unit of typically 5 m clear internal height, with areas for office, storage and dispatch.
- Largely naturally ventilated with occasional local mechanical extraction.
- Warm air or radiant heater units, and 1.5 shift operation with heating to 16-18°C plus frost protection only at night.
- Lighting generally to 300 lux by fluorescent or low-bay high pressure sodium fittings.
- Average 10% rooflights.

This type of building may also be used for light engineering and electronic equipment assembly.

Factory-office buildings

- Modern office-like space with little differentiation between production, office and storage areas.
- Clear internal height 4 m, often with lower suspended ceilings in office parts.
- Fluorescent lighting typically to 500 lux.
- Flexitime operation with typically 10 occupied hours and 2 cleaning hours per day.
- Perimeter windows, often double glazed.
- Ducted warm air heating to internal spaces, with radiators at the perimeter, typically to 20°C with frost protection out-of-hours.
- Some local mechanical ventilation or air-conditioning. (Note that any significant air-conditioning will in general increase energy consumption. See Energy Consumption Guide 19 and Good Practice Guide 71.)

General manufacturing buildings

- Typically 8 m clear to accommodate tall equipment, gantry cranes and local storage racking.
- Illuminated to typically 200 lux with high pressure sodium, mercury halide or fluorescent fittings. Clerestory and rooflights may be present, but these are often dirty or obstructed, giving little effective daylight.
- Mezzanine areas in places.
- Two shift operation.
- Warm air, radiant or steam heating to 16°C, frost protection otherwise.
- Ridge ventilation or mechanical ventilation to areas of high process heat gain.
- Space heating consumption can be highly variable depending on the heat output and ventilation needs of the process.

This type of building often also accommodates industries such as plastics, large scale printing, heavy engineering and food.

ENERGY AND COST PROFILES

Figures 4 and 5 indicate three categories of annual energy consumption and cost.

- **Typical**, not including recently completed buildings.
- **Improved**, as 'Typical' after upgrading.
- **New**, recently completed to good energy efficiency standards.

Figures 4 and 5 provide comparative data on the following.

- Fossil fuel for space heating and domestic hot water, but not for process purposes.
- Electricity for fans (including fans in warm air heaters and burners), pumps and controls.
- Electricity for lighting.
- Electricity for other purposes, including external lighting, office equipment, local catering equipment and ancillaries such as security systems and fork lift truck chargers.

It can be seen that heating usually accounts for the majority of energy use (figure 4), but half or less of energy cost (figure 5).

Energy use by processes and in special areas varies greatly from site to site and is not shown here. It tends to be small in 'Storage and Distribution' buildings unless there are major conveyers, refrigeration, or similar items, around 50 kWh/m^2 of electricity in 'Light Manufacturing' and 'Factory-Office', and very variable in both magnitude and fuel mix in 'General Manufacturing'.

Typical 'small site' fuel prices (see 'Typical fuel costs') have been used to produce figure 5 since these illustrations are for individual buildings. On large sites, lower fuel costs may be appropriate.

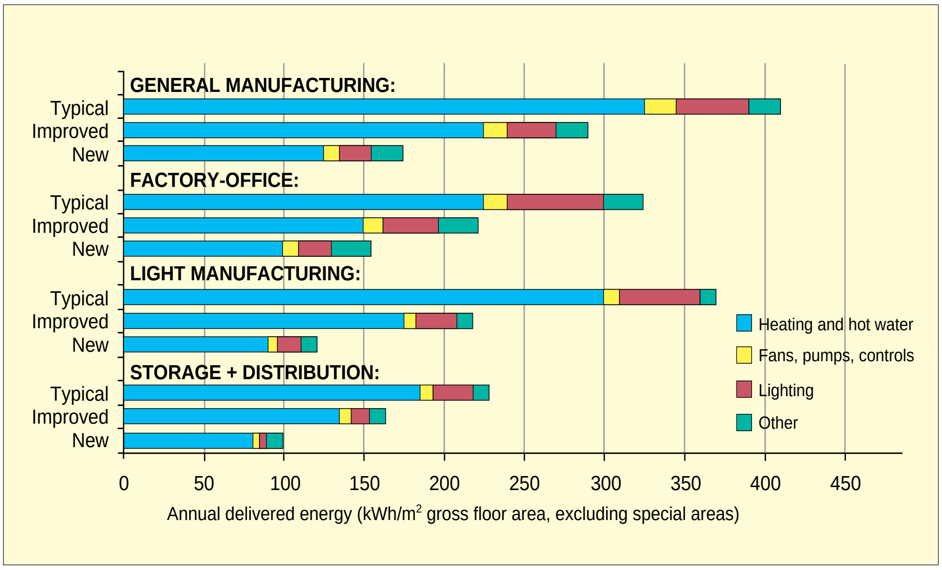


Figure 4 Buildings-related energy consumption (data on page 11)

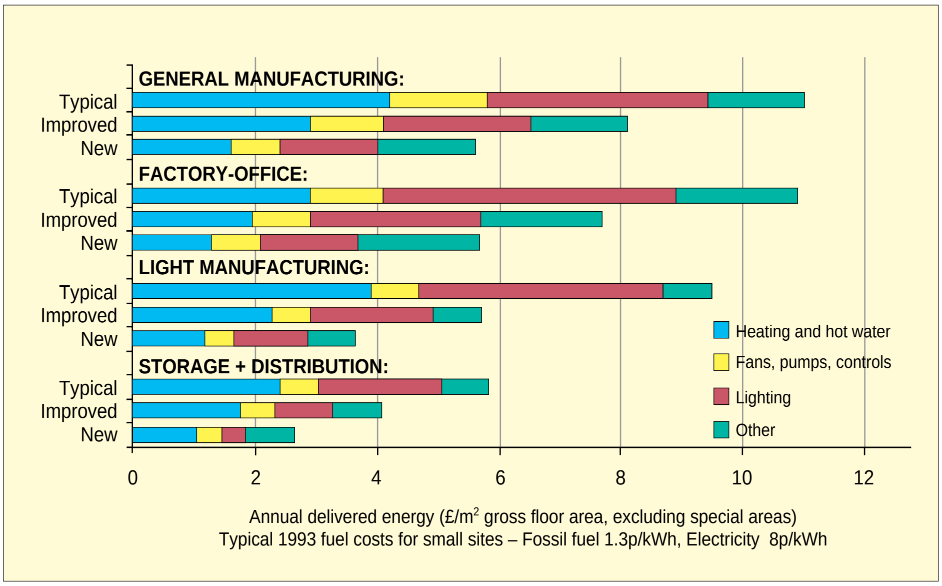


Figure 5 Buildings-related energy costs (data on page 11)

HOW DO YOUR BUILDINGS COMPARE?

(See also pages 8 and 9)

Typical. Many industrial buildings use considerably more energy than the 'Typical' values (figures 4 and 5). Even after taking account of special circumstances, much avoidable energy consumption occurs, and most buildings have considerable scope for cost-effective improvement. The following pages outline where wastage is often found and what can be done to avoid it.

Improved. The 'Improved' levels (figures 4 and 5) can be achieved when buildings are upgraded, refurbished and managed to good standards, using available cost-effective methods. This assumes that influencing factors, discussed on pages 8 and 9, do not have an overriding effect. Heating and lighting consumption costs can often be reduced by one-third or more, as Good Practice Case Studies show. Even if you achieve this performance, you may be able to improve further.

New. 'New' target levels (figures 4 and 5) can be achieved by buildings designed, constructed and serviced to excellent standards in **all** individual aspects relevant to energy use. This assumes that influencing factors, discussed on pages 8 and 9, do not have an overriding effect. Heating costs are reduced substantially, with smaller but significant savings on electricity.

Typical fuel costs

Fuel costs vary with site size, region, contract and load profile. Costs per kWh are usually lower for larger and more intensively serviced sites. These sites have more bargaining power with the supply industries. The following are typical of unit prices (1993) in industry and have been used in figures 3, 5 and 7. Fossil fuel is largely gas, oil and coal.

Electricity	small site	8.0 p/kWh
	large site	5.0 p/kWh
Fossil fuels	small site	1.3 p/kWh
	large site	1.0 p/kWh

Some large sites may pay even less; 0.8p, and occasionally as little as 0.5p for coal, fuel oil or interruptible gas, and 4p or less for electricity (about half this for off-peak). The cost of electricity from appropriate combined heat and power (CHP) systems may be lower still.

Electrical costs also vary with end use. Lower than average rates are attributable to continuously running process equipment with better load factors, and to cooling systems which run in summer only thereby avoiding high winter maximum demand charges. Higher than average rates will apply for equipment and systems used only intermittently, especially those with peak demands on winter days (eg direct electric heating and steam humidification).

Checklist

Understanding where the energy goes, and identifying waste is a major step to achieving energy savings.

- **Collect** your energy use and cost data for the past year or more.
- **Obtain or measure** the treated floor area of your buildings. (See box on page 5).
- **Consider** how overall annual electricity and fossil fuel consumption relates to the examples given here, and whether the monthly energy consumption pattern relates sensibly to the weather and the pattern of use and production (see pages 8 and 9).
- **Try to understand** features of your buildings which might cause the consumption levels to be particularly high or low. If your electricity is on a Day/Night tariff the information can help you to estimate night time loads and consider whether these are reasonable. If not, portable monitoring and recording equipment may be purchased or hired, with or without consultancy support.
- **Install** meters, if necessary, to check the amount and pattern of energy consumption by major individual items.
- **Review** the information they provide regularly.
- **Concentrate** at first on the buildings, processes or features which are particularly high energy consumers or offer the greatest potential for energy saving.
- **Identify and prioritise** the measures. Simple, highly cost-effective measures can sometimes create cash reserves from utility budgets to help finance subsequent projects.
- **Exploit opportunities.** The best time to implement energy saving measures is on the back of an essential project, for example maintenance, alteration, re-equipment and refurbishment. Think ahead so you make best use of such opportunities.
- **Keep it simple.** Don't use any more, or more complex, technology than necessary to solve the problem effectively. Avoid creating unnecessary maintenance or management burdens.
- **Refer** to other guidance material as appropriate, seek second opinions, and if appropriate, professional advice.

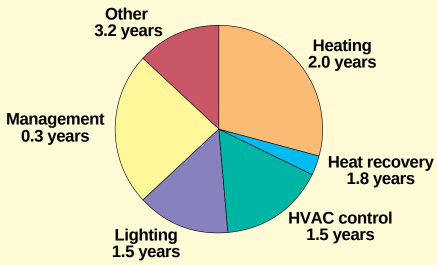
SCOPE FOR ENERGY SAVINGS

In nearly every building energy wastage occurs which can be reduced cost-effectively by management action and/or technical measures. While sites, buildings, processes, and services with the highest energy consumption merit the earliest attention, similar percentage savings can often be made in less energy intensive sites and buildings. Figure 2 shows that in many industry sectors space heating and other uses are significant in comparison with process energy.

Averaged over all the energy surveys analysed, **the cost savings from recommended building-related measures were as large as those from process-related measures.** The recommended building-related measures would save 155 kWh/m^2 of fossil fuel and 17 kWh/m^2 of electricity, worth approximately £1.55/m^2 and £0.85/m^2 respectively at the standardised large site unit prices, with an average payback period of two years. The comparable values for recommended process-related measures are £1.45/m^2 of fossil fuel and £1.25/m^2 of electricity. It is therefore incorrect to dismiss building-related energy savings as trivial, as is too often the case.

EFFECT OF INDIVIDUAL MEASURES

Figures 6 and 7 give details of the average savings from individual recommended measures for all the surveys analysed. For sites where a given measure was recommended, the average savings attributable were two or three times higher, and on individual sites sometimes more again. (This is because each survey included different packages of measures, and moreover some areas of saving were overlooked, eg many surveys did not mention lighting or management.) In addition, some measures are alternatives: for instance changing from central boiler plant to local unit heaters is classified here as a saving in heat distribution, not boiler measures. The denominator for these values is the total floor area of the site, so that items which have only a local impact, like changes to a particular type of lighting or to a local ventilation system, may be individually significant and cost-effective, but have less effect on the totals than site-wide measures like heat distribution and monitoring and targeting..



The pie chart indicates the relative size of energy cost savings for different types of recommended measures. The number below each item indicates the average payback period in years, which varies widely for individual projects and sites. **Nearly half the savings are heating related, a quarter attributable to better management (including metering, monitoring and targeting) and an eighth to lighting.**

Figure 6

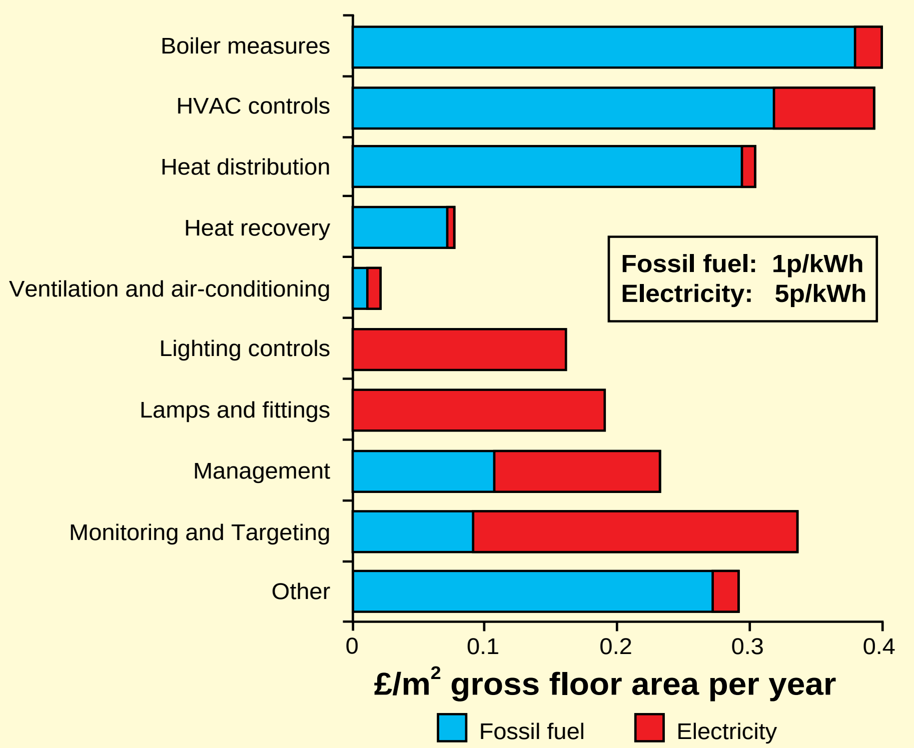


Figure 7 Annual energy cost savings from individual measures

STRATEGIC CONSIDERATIONS

Sometimes the provision and use of buildings and services needs thorough review. There may be significant energy and non-energy benefits from doing so. Are the ways in which the buildings are used and serviced really appropriate? Sometimes continuous activities are scattered about a largely unmanned site, with many services to operate them. Could they be grouped closer together or independently serviced?

With technical change, some industrial tasks are becoming increasingly similar to office or light manufacturing work but may still be housed in tall, poorly insulated and over ventilated spaces originally built and serviced for heavy engineering. Are these still necessary and appropriate, or can they be rationalised and upgraded, at least in the long term?

A strategic review will normally involve senior management, whose commitment and support are important to a coherent approach to energy efficiency. The EEO 'Making a Corporate Commitment Campaign' (see page 12) promotes the value of energy efficiency to senior managers. It encourages regular analysis of energy at senior management level, development of an energy policy, and appropriate allocation of time and staff to control of energy use. Such a review can result in significant energy savings, with associated environmental benefits from reduced emission of CO_2 and other greenhouse gases. The BREEAM scheme (see page 12) may be used to assess environmental impact of new and existing office buildings, and of new industrial buildings.

MANAGEMENT

Good management is essential to energy efficiency. Very few energy saving measures are 'fit-and-forget'; they need looking after. Somebody (often the site engineer) must be responsible for energy management and report direct to the general manager, and together they should aim to achieve the following.

- Specify performance standards and operating hours required. Ensure these are met with minimum energy use.
- Carry out regular audits to check equipment, controls and their operation. Ensure effective maintenance occurs.
- Keep fuel consumption and costs under close review.
- Ensure staff are kept informed and motivated.
- Consider, and keep considering how energy efficiency of buildings and processes can be improved.
- Seek advice where necessary.

Energy management is considered in detail in General Information Reports 12 and 13 (see page 12). These describe a matrix which enables self assessment of key energy management issues, and identification of changes which are necessary. General Information Report 14 describes some Case studies, including British Gas NW saving £700 000 a year on energy use in its buildings, J Sainsbury's with an annual fuel bill of £10 million lower than without an energy management programme, and Manchester University which has cut energy consumption by 36% in the last 8 years.

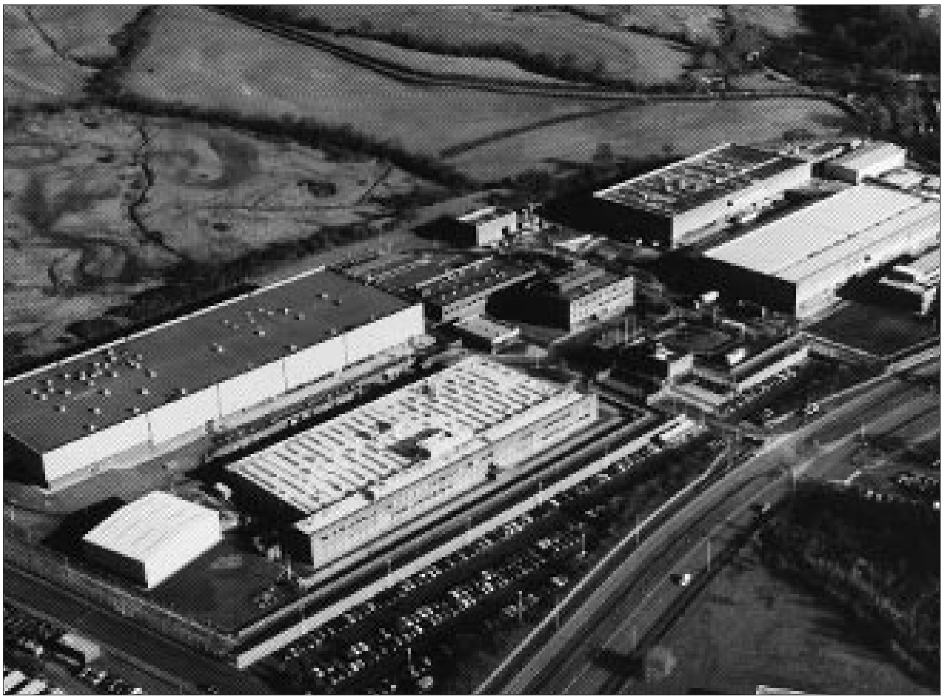


Figure 8   The Royal Mint has an energy management system based on manual meter readings and a computer spreadsheet to produce information for managers. As a direct result, unnecessary use of ventilation fans has ceased, replacement lighting installed, boiler plant decentralised, and variable speed drives fitted. Savings of £62 000/year have resulted from an investment of £12 000 (payback period ten weeks). Significant water savings have also been made. Good Practice Case Study 179 (ETSU).

While new technological developments can help save energy, first make sure that what you have is working efficiently. With little or no capital investment one can usually identify many 'good housekeeping' measures which offer immediate benefits, generate credibility and may even create cash reserves for future investment. An agreed policy which defines energy management procedures, budgets, and investments, will provide a vital foundation for effective management and control of energy costs.

MONITORING AND TARGETING (M&T)

If you are not monitoring your energy, you probably don't know much about it, and it will certainly be difficult to manage. Monitoring and understanding past energy consumption (see CIBSE AM6, chapter 6), and setting and reviewing future targets is an established and effective method, but is not carried out on most sites. Monitoring provides the information necessary to identify the priority areas for action, and to measure the effect of any actions taken. In addition unusual energy consumption patterns can be investigated, often giving advance warning of failures in equipment, controls or procedures.

Having gained an understanding of the overall pattern of fuel consumption of the site, sub-metering should be considered. (One can often find entire buildings with no meters at all!) From this information, and a consideration of the actions to be taken, future consumption targets can be set to motivate the reduction of energy consumption and costs.

You may also be paying more for your fuel and electricity than you should. More economical tariffs may be available and one can often take steps to improve power factors or load profiles, particularly on larger sites. Computers can help with the energy and cost analysis, and where necessary with continuous monitoring. They can also help reduce electrical costs and avoid penalties by disconnecting non-essential loads at peak times when high maximum demand charges would be incurred.

BUILDING FABRIC MEASURES

Fabric insulation measures, although offering major savings in heat loss and heating requirement, are not prominent in survey recommendations, and form only part of the 'other' category. While many industrial buildings are poorly insulated, insulation is often more disruptive and expensive to improve than shortcomings in plant, control and management.

Notes on floor area

When comparing buildings and sites, annual energy consumption per unit floor area is normally used (building volumes can also be used, see page 9). It is important to consider the likely accuracy, and where necessary check measurements. The units used here are gross internal floor area in enclosed buildings. Other definitions, such as treated volume or floor area, which specifically excludes spaces that are not directly heated, would be preferable.

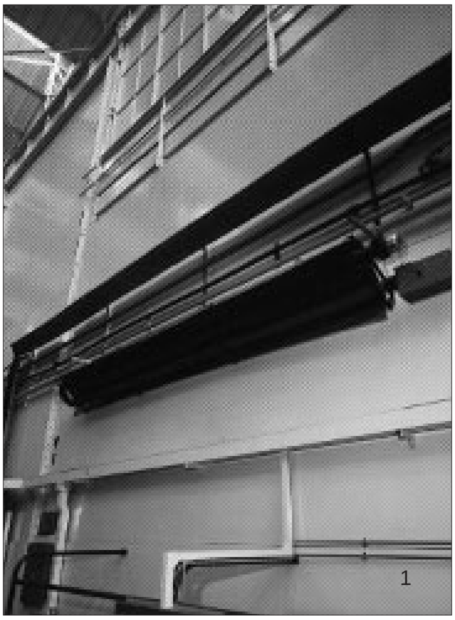


Figure 9 GEC Alsthom more than halved fossil fuel consumption by replacing central steam mains with gas-fired radiant heaters in the works (1), high efficiency boilers for central heating in the offices, and local steam generators for process. An air lobby was also constructed (2), and roofing (in need of repair) insulated.

Good construction and insulation practice is best applied in the original design and construction, and in major refurbishment where, as part of a larger package of work, it becomes more cost-effective and less disruptive. Good Practice Guides 61 and 62 give detailed information on good practice design and occupation of advance factory units, and much of this information is also valid for larger buildings, and for refurbishments. Management should make sure that opportunities for upgrading are not missed, either for lack of thought or budget. Often maintenance budgets provide for replacement 'as was', but not for upgrading to modern energy efficient standards with long term cost savings. If this is the case, capital and revenue budget arrangements should be reviewed to ensure savings opportunities are not lost.

Most UK industrial buildings have excessive air leakage, even many new ones. Unwanted air infiltration can easily double the heating costs. While again this is best considered in the original design or as part of a refurbishment, in existing buildings some major sources of leakage can be tackled cost-effectively. Leakage frequently occurs at junctions such as at eaves, ridges and where light cladding meets low level brickwork. It also occurs where ventilator controls are absent, ineffective, or inappropriately used. Heat loss through large doors can be reduced through insulated designs with effective seals for when closed. Seals at loading docks, and fast-closing doors for frequently used doorways are available and cost-effective, provided they are also properly maintained. For more guidance see Good Practice Guides 61 and 62.

HEATING RELATED MEASURES

Much waste occurs in heat generation, in site distribution, through inefficient systems, and through poor control and management. Appreciable savings are often possible.

Heat generation

Heating plant is often inefficient because it is old, poorly maintained, poorly insulated, or unsatisfactorily operated. Early action should be taken and guidance is given in Good Practice Guide 30 (ETSU). Even where older plant is in good condition, replacement or upgrading may be cost-effective, particularly if the system necessarily provides both space and process heating and running hours are long. For low temperature hot water (LTHW) and central heating, modern condensing boilers may be appropriate (see Good Practice Guide 16 and General Information Leaflet 1).

Heat distribution

Site mains may have very high standing losses owing to sprawling site layout, poor or badly maintained insulation, extended running hours, and excess circulation when demand is low. On older sites, extensive mains may once have fed a wide range of processes but now supply primarily space heating and domestic hot water. On these sites summer efficiencies may fall to 10% or less. Steam systems are particularly vulnerable with their higher temperatures and steam leaks. Better insulation, better control, variable volume pumping, and local point-of-use water heating in summer can reduce energy costs. However, where steam is no longer essential, decentralised plant should be considered. This nearly always brings major savings in energy and maintenance costs, even if the price of fuel (typically firm gas or light oil) for the decentralised plant is higher.

Heating systems

Many warm air systems give barely adequate comfort at floor level while hot air collects below the roof, causing high conduction and ventilation heat losses. Where this happens, air distribution should be improved, preferably by modifying the system. Ducted systems are more expensive but can provide better distribution than unit heaters. Ceiling fans can help destratify the air and provide beneficial air movement in summer. Fans which blow air upwards from low level can be equally effective and cause less draughts, though they tend to be more expensive.

Often the whole space is heated when this is not essential, as some areas are not occupied. In this case a lower level of overall heating with supplementary local heating should be considered. Radiant heaters can be particularly suitable for heating localised areas. For more continuous heating, the differences in energy consumption between radiant and warm air systems may be less pronounced.

Warehouses are sometimes heated primarily to lower relative humidity and so maintain product quality. Dehumidification can be more energy efficient for this purpose, particularly for longer term storage in well sealed buildings.

Heat recovery

In principle waste process heat can be used for space heating. In practice this seldom occurs, and energy is often consumed to condition the incoming make-up air or water. Heat recovery within the process normally gives greatest benefits, and figures 6 and 7 show that process-to-building heat recovery opportunities are usually fairly limited. However, heat recovery to buildings can be appropriate, as in New Practice Final Profile 5, and Demonstration Scheme Expanded Project Profiles 28 and 77 (ETSU). Good Practice Guide 13 (ETSU) gives guidance on heat recovery.

Combined heat and power (CHP)

With CHP, electricity is generated on site and the 'waste' heat is available for space and process heating requirements. Capital investment is normally high, with payback periods of 4 or 5 years in suitable applications. Feasibility usually depends primarily on the process and requires multi-shift operation and substantial year-round requirement of hot water or low-pressure steam

Energy units

Energy units are in kilowatt-hours (kWh), the unit in which electricity and gas is billed. For other fuels and units, gross calorific values (CVs) are as follows:

Natural Gas		29.31 kWh/therm.
LP Gas	Approx	13 750 kWh/tonne.
Oil	Gas-oil	10.6 kWh/litre.
	Light fuel oil	11.2 kWh/litre.
	Heavy fuel oil	11.4 kWh/litre.
Coal	Approx	7780 kWh/tonne.

Note: 1 therm = 100 000 Btu (British Thermal Units), and 1 kWh = 3.6 MJ. Nett calorific values (more commonly used in countries other than the UK) do not include heat lost in vapourising water present in combustion. They are about 5% lower for solid and liquid fuels, and about 10% lower for gases. Note when choosing heating equipment, efficiency values look higher when based on nett CV.

to be cost-effective. Good Practice Guides 1, 3 and 43 (ETSU) give guidance.

MECHANICAL VENTILATION

While not offering major opportunities overall, where present, mechanical ventilation and air-conditioning have much potential for waste. This can be caused by unnecessarily high fan power, excessive air volumes, poor air distribution, and in particular high running hours and poor control. Control problems include: unnecessarily high outside air volumes, heating and cooling systems fighting each other, and unnecessary levels of humidification or dehumidification. Systems should be checked regularly and carefully for effective function and operation. Energy surveys often identify over-centralised systems running at full capacity overnight and weekends, when demands are small or localised. In these circumstances, local plant, effective zoning, or variable capacity operation are effective, and much more economical.

LIGHTING MEASURES

Energy efficient lighting can be highly cost-effective. For lights which need to be on for long hours, the most efficient sources and fittings should be used. If lights are on unnecessarily, then controls may need attention. Often a case can be made for doing both. CIBSE Lighting Guide LG1 discusses lighting requirements for the industrial environment, while the CIBSE Code for Interior Lighting gives information on energy efficiency standards.

Lamp efficacy has improved steadily over recent years. Sometimes existing fittings can take better lamps directly, for example 26 mm diameter fluorescent tubes in place of 38 mm ones, provided the existing control gear is switchstart. In corridors, WCs, and similar areas, compact fluorescent lamps have made the tungsten light bulb (GLS) redundant, and their long life also saves maintenance time.

Replacing fittings as little as 5-10 years old can often be justified. Some existing systems use well over 5 W/m^2 per 100 lux. If kept reasonably clean, one can now light most industrial space with an installed loading of under 2 W/m^2 per 100 lux with modern high-intensity discharge fittings and around 2.5 W/m^2 per 100 lux with fluorescent triphosphor tubes, efficient fittings, and electronic high-frequency ballasts.

Lights are often left on unnecessarily because switching is inadequate. Better manual switches may be sufficient, but only if they are well located, clearly marked and staff appropriately trained. With good daylight and clean, unobstructed windows, photoelectric control may be appropriate but there should always be local override switches to meet individual needs. In intermittently used spaces, storage areas, and particularly where people cannot easily operate light switches (for example fork-lift truck drivers and people carrying or pushing equipment), electronic presence-sensing controls can reduce consumption substantially. Occupancy sensing can also work well in covered car parks, where it may also be linked to the ventilation system.

How to check your lighting load

Select typical areas of the building, count the number of lamps of each kind in each, multiply by their nominal ratings (in watts), add control gear losses for fluorescent and discharge lighting (assume 20% unless manufacturer's data is available). Divide the total by the appropriate floor area to give watts/m^2. Measure the average illuminance to calculate watts/m^2 per 100 lux.

Figure 10 At L'Oreal Golden, electricity bills were over 70% lower, and a better quality of light achieved, than from a standard installation, with the extra cost recouped in less than two years. This resulted from selection of efficient fluorescent lamps and ballasts, and appropriate photocell and manual controls. (GPCS 158, to be published by BRECSU.)

External lighting may also offer good scope for improved efficiency, both with more efficient lamps and fittings, and by making sure that lamps are not on during daylight hours.

CONTROL SYSTEMS

Automatic control technology must not be taken for granted: it is an aid to good management, not a substitute for it. Controls often allow systems to run for too long and at too high an output. Try to create an environment where things that do not need to be on all the time revert to 'off' automatically and if hidden, give clear indications that they are running.

Computer-based building energy management systems (BEMS) often suit larger sites with permanent operating staff. In smaller buildings, simple controls and clear, straight-forward operation (for example, 'for two hours extra heat – press here') may be more readily understood and effectively operated by occupants and contractors. Areas regularly used outside normal hours should be separately zoned and controlled.

SUMMARY

Energy efficiency is not only - or even mainly - about fuel for heating. Electricity costs are often significant, and offer good scope for cost-effective energy savings.

Regarding heating, insulation is only a small part of the story. Buildings and sites, even well-insulated ones, often cost more to heat than they should owing to inefficiencies in plant, distribution, control and management. Steam systems are particularly vulnerable to this owing to their high temperatures and steam leaks. The situation is often worsened when systems are unnecessarily oversized and run in a poorly controlled manner in summer to meet localised process, humidification or reheat requirements, or to make small amounts of hot tap water. A strategic review is often worthwhile.

In newer buildings, in spite of their better insulation, high heat losses due to leakage are still common. If they are to be avoided, attention to detail in design, construction and refurbishment is required. Where mechanical ventilation or air-conditioning is incorporated, performance needs to be monitored carefully. The opportunities for energy waste are much increased if the systems are poorly designed, commissioned, controlled or operated.

Lighting often offers major savings, in particular through the use of more efficient lamps and fittings, and better and more appropriate controls.

However, while building design and modern technology can reduce energy requirements, whether the building is ultimately energy efficient depends principally on the management, the original requirements of the building, and the way in which it is operated and maintained. Energy efficiency is part of good management practice. If staff resources are not available, consultants and energy management contractors are available who can help.

EFFECT OF PROCESS

Figure 11 shows the proportions of total energy costs which are building-related. There is considerable variability and no simple relationship between building and process energy (see also figure 2). Reasons for this include the following effects.

- Heat output from 'clean' processes can lower space heating requirements.
- 'Dirty' processes require ventilation which often adds to building electrical requirements and heating loads.
- Excessive process heat not only requires more ventilation and cooling, but where the make-up air needs tempering it may even increase heating energy use.
- Some processes require better lighting over larger areas than others: the need varies with industry and process.
- Some processes have special and energy-demanding air quality requirements.

The influence of such effects on energy use in different sectors (see figure 2) is outlined below.

- **Cold Food and Cooked Food** are relatively high process and low building energy users. There is considerable variation between sites. Heating requirements are particularly low. Buildings often enclose bulky equipment which runs continuously and either heats much of the space or creates its own refrigerated environment. Building electrical requirements are quite high, for ventilation, lighting, and for food preparation areas.
- **Electronics, Plastics and Textiles** use average amounts of energy for heating (median 300 kWh/m^2 per year) and less electricity for building-related purposes, except where high light levels and special ventilation for air and product quality are required.
- **General Manufacturing** has a similar looking profile, with more 'Other' uses such as compressed air. Average space heating consumption is very similar to the group above. This is a result of various opposing effects such as taller and older buildings tending to increase consumption, and less demanding performance requirements tending to reduce it.
- **Light Manufacturing and Engineering** has lower process energy which neither heavily subsidises the building services nor makes severe demands upon them, so heating use is average. These categories represent a high proportion of industrial floorspace. Buildings and areas like this also occur on many larger, more process intensive sites.
- **Chemical Plant, and Paper** have round-the-clock processes with high energy requirements which dwarf everything else. Building energy use, while small in proportion, is nevertheless similar to that in other industries that have high building energy use, and offers similar scope for energy savings.

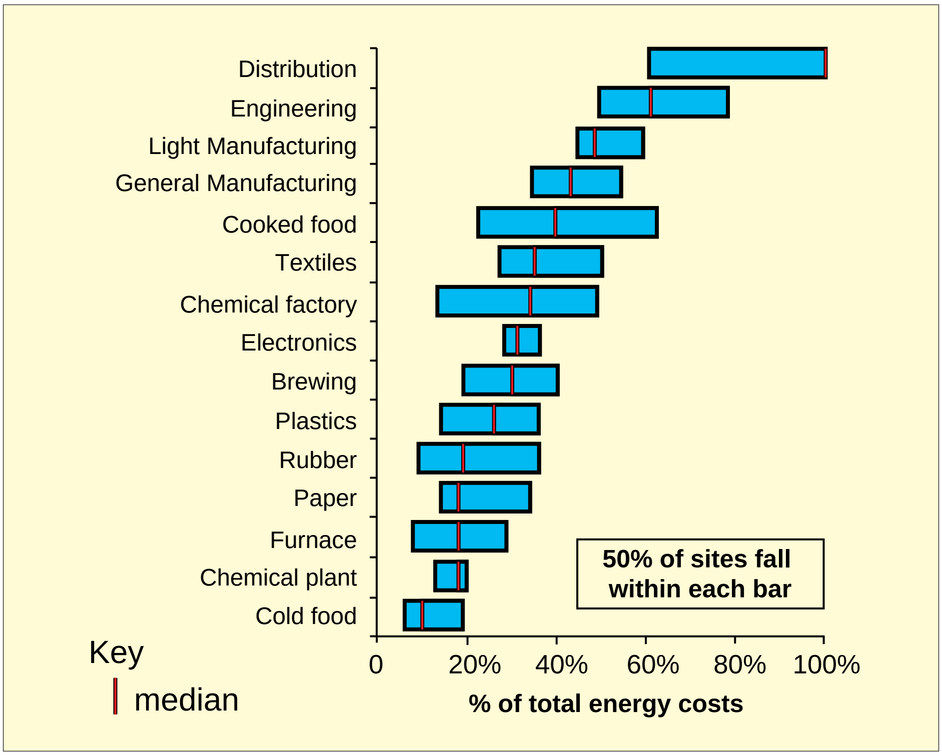


Figure 11 Buildings-related proportion of total energy costs

IMPACT OF PROCESS ON BUILDING SPACES

Patterns of buildings energy consumption in relation to processes can be considered in the following three main classes.

Process Incidental
The process makes few demands upon the internal environment. In many ways requirements are similar to an office, except that the space may be taller, the building services less sophisticated, and the environmental conditions often less demanding.

Process Significant
Servicing is dictated primarily by the comfort and performance requirements of the people in the building, but affected by the needs of the process, for example humidification for textile weaving.

Process Dominant
The process either demands very little of its buildings (it may even be outside) or it entirely dominates the situation, either for product quality or for health and safety. While such areas are beyond the scope of this Guide, the general points made in this Guide on control, management and improving individual systems like ventilation or lighting will still apply.

NON-PROCESS BUILDING SPACES

Sites also contain other types of spaces. These may be in separate buildings, or within the same building, perhaps partitioned off. They include the following.

Storage and warehousing
Servicing levels and requirements are usually low, with reduced heating, ventilation and lighting, except for special purposes (for example cold stores) or sometimes when part of a larger multi-purpose space. Typically there is high-bay racking for bulk mechanical handling, some low shelving for hand-order picking, open areas for bulky items, and an arrival/dispatch area.

Office and social facilities
Most sites have at least a small office space area, either in the general space, at the edge of the building, or in separate buildings. There may also be canteen and social facilities, in which the kitchen is usually the main energy influence. Energy Consumption Guide 19 gives more information on energy use in office buildings.

SPECIAL AREAS AND SUB-METERING

Often 'Process Dominant' production space is restricted to a few areas (for example foundries, or clean rooms). These are best considered as special cases. Non-production space may also contain special areas like kitchens, laboratories, and computer suites. Ideally energy supplies to any special area or item responsible for significant annual energy consumption should be separately metered and monitored. An approximate guide to 'significant' is greater than £1000 per year of gas or electricity or £5000 per year of hot water or steam. The cost levels differ because capital and maintenance costs of steam and hot water metering tend to be higher. For smaller items or components, simple hours-run meters can be useful. Gas and electricity to kitchens which serve over 100 hot meals per day should also be metered.

MAKING THE COMPARISONS

A detailed breakdown is not essential to compare your building's energy consumption with figures 4 and 5. You can first consider annual energy consumption or cost of fossil fuels and electricity, and then move on into more detail as necessary.

INFLUENCING FACTORS

Your buildings, processes and intensity of use may well differ from the examples shown in figures 4 and 5. Some typical sources of variation are discussed here.

Building Dimensions

For similar temperature standards, heating energy consumption increases approximately in direct proportion to ceiling height, with two exceptions.

- Heating which allows hot air to accumulate at a high level gets increasingly wasteful with building height. Poorly designed warm air systems are particularly vulnerable. This problem can be identified by measuring the temperature gradient.

- Energy use by localised and radiant heating systems is less affected by building height.

Building height has less affect on energy use for other purposes. For example, there may be no relationship at all with process energy, external lighting, or with requirements which depend on the number of people such as hot water, catering, and office equipment. Lighting energy is only weakly affected by building height, particularly in large spaces.

Sometimes the greater volume and height may reduce the need for mechanical ventilation and cooling.

Floor area has no clear affect on energy consumption per unit area. Smaller buildings have proportionally more external surface area, so that conduction and air leakage heat losses tend to be relatively larger, particularly for less than 1000 m^2 floor area. However, larger and deeper buildings tend to need more deliberate ventilation, natural or mechanical, which increases air change rates and counteracts this effect. They are also more likely to have permanent artificial lighting.

Hours of Use

The more intensively used a building, the more energy it consumes. However, the effect on building-related energy is not always as direct as one might expect. In General Manufacturing, for example, the review of energy surveys found little direct correlation between building-related energy use and the number of shifts worked. Not only was additional process heat offsetting space heating requirements, but the more intensively operated plants tended to be newer, better insulated and more efficiently lit. Various influences are outlined below.

- In relatively well-insulated and heavyweight buildings, much of the heating energy is expended in raising them to the necessary temperature, and not in maintaining the temperature. A change from 5-day single-shift to round-the-clock operation may increase heating energy requirements by only perhaps 30%, and some or all of this may be offset by the extra internal heat gains from equipment, people and lighting.

- Lightweight and poorly insulated buildings are much more sensitive; here a similar change may double the heating energy use unless there are large heat gains from process and occupancy.

- In buildings with high ventilation requirements however, heating energy use is almost directly proportional to hours of use, so a similar change could triple energy consumption, not only for heating but also for associated fans, cooling and humidity control systems. Careful design, control and management of mechanical ventilation and air-conditioning systems is therefore essential. In systems which are likely to run for long hours, energy saving features such as variable speed operation and heat recovery may well be cost-effective.

Standards

High standards, for example of temperature, humidity, lighting or air quality, tend to require higher energy inputs. But are the standards appropriate, inadequate or wasteful, or can they be restricted to a smaller area?

Weather

A building on an exposed site will require more heat than if sheltered. Heat loss will be greater, owing to increased air leakage through the building. Heating energy consumption can be expected to be about 10% lower on sheltered and urban sites and 10% higher on exposed ones. However, when comparing similar buildings in use, the effect is often less marked as occupiers of exposed buildings are more likely to have taken steps to reduce air leakage.

Heating energy consumption is also affected by outside temperature, which is usually measured by the number of 'degree-days' below 15.5°C (see Fuel Efficiency Booklet No 7). Other temperature bases can also be used.

Monthly degree-day values are published for standard regions in the UK. Degree-day values, appropriate to specific sites, may be collected by data loggers or purchased from specialist companies. Figures 4 and 5 assume a standard value of 2462 degree-days per year (a 20 year UK average). Typically this varies by ±10% with location (see figure 12) and a further ±10% year-on-year.

DEGREE - DAYS

Region	1992/93	20 year average
1 Thames Valley	1932	2070
2 South Eastern	2191	2338
3 Southern	2152	2263
4 South Western	1850	1898
5 Severn Valley	1824	1980
6 Midlands	2326	2478
7 West Pennines	2286	2352
8 Northern Western	2426	2549
9 Borders	2511	2620
10 North Eastern	2366	2501
11 East Pennines	2340	2437
12 East Anglia	2269	2380
13 West Scotland	2519	2619
14 East Scotland	2651	2690
15 N E Scotland	2707	2810
16 Wales	2178	2274
17 Northern Ireland	2463	2489

'Degree-days' is the cumulative sum of the number of °C that the average daily temperature is below 15.5 °C each day. Monthly degree-days values are given in 'Energy Management', published by the Energy Efficiency Office.

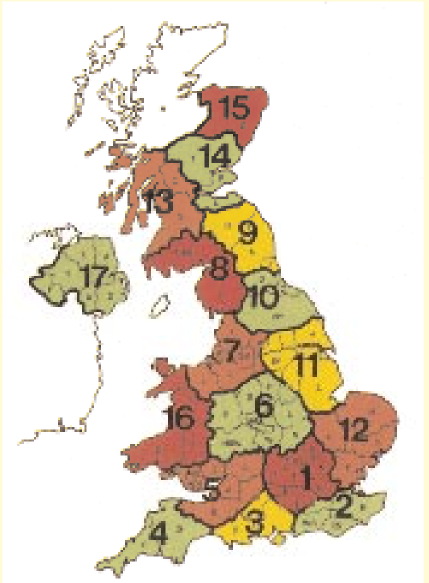


Figure 12 Degree-days

NORMALISATION

To compare different buildings and sites, and to relate the consumption of an individual building to changes in occupancy hours, production levels, exposure, winter severity, and other factors, methods of 'normalisation' are available.

However, normalisation can be misused and should only be carried out where the proposed corrections and reasons for their use are clearly understood. A simple guideline is to only correct for a factor after confirming its effect on energy consumption. Guidance on deriving relationships for individual buildings is given in CIBSE AM6 (page 47).

Normalised comparisons between different buildings and sites can sometimes obscure important factors. For instance, sites with long hours of use may give a low normalised energy consumption value, implying a low priority for energy saving. This may prevent management considering whether the high hours of use could be reduced. Moreover, the intensity of use may make these sites good candidates for cost-effective investments in energy efficiency measures.

Before making any corrections, one should therefore examine the raw data and consider the reasons why energy use might be high (eg, regular multi-shift operation) or low (eg, some empty or under used buildings on the site). Moreover, make sure that presentation of your conclusions to management is not obscured by the normalisation procedure.

	Shifts*	Building-related energy (kWh/m² per year) Space heating	Other uses	Total buildings	Process energy (kWh/m² per year)
Laboratories	1.5	669	538	1207	346
Chemical plant	3.0	543	85	628	3589
General manufacturing	2.3	328	81	409	495
Paper	3.0	298	88	386	2636
Electronics	2.5	298	65	363	341
Textiles	2.5	303	38	341	479
Plastics	2.3	288	52	340	532
Rubber	2.6	233	93	326	967
Light manufacturing	1.7	286	38	324	82
Engineering	1.7	257	45	302	85
Cooked food	1.8	170	121	291	795
Furnace/foundry	2.1	245	34	279	1012
Chemical factory	2.4	249	28	277	346
Distribution	1.0	164	44	208	0
Cold food	2.5	80	93	173	1247

*Average shifts worked

Table1 Energy consumption and industry type (see figure 2)

	Shifts*	Building-related energy (£/m² per year) Fossil	Electricity	Total
Laboratories	1.5	£6.69	£26.90	£33.59
Chemical plant	3.0	£5.43	£4.25	£9.68
Cooked food	1.8	£1.70	£6.05	£7.75
Paper	3.0	£2.98	£4.40	£7.38
General manufacturing	2.3	£3.28	£4.05	£7.33
Rubber	2.6	£2.33	£4.65	£6.98
Electronics	2.5	£2.98	£3.25	£6.23
Plastics	2.3	£2.88	£2.60	£5.48
Cold food	2.5	£0.80	£4.65	£5.45
Textiles	2.5	£3.03	£1.90	£4.93
Engineering	1.7	£2.57	£2.25	£4.82
Light manufacturing	1.7	£2.86	£1.90	£4.76
Furnace/foundry	2.1	£2.45	£1.70	£4.15
Chemical factory	2.4	£2.49	£1.40	£3.89
Distribution	1.0	£1.64	£2.20	£3.84

*Average shifts worked

Table 2 Energy cost and industry type – Fossil fuel 1p/kWh, Electricity 5p/kWh (see figure 3)

	Building-related energy (kWh/m² per year)					
	Heating and hot water (fossil)	Fans, pumps, controls (electricity)	Lighting (electricity)	Other (electricity)	Total electricity	Total
GENERAL MANUFACTURING						
Typical	325	20	45	20	85	410
Improved	225	15	30	20	65	290
New	125	10	20	20	50	175
FACTORY-OFFICE						
Typical	225	15	60	25	100	325
Improved	150	12	35	25	72	222
New	100	10	20	25	55	155
LIGHT MANUFACTURING						
Typical	300	10	50	10	70	370
Improved	175	8	25	10	43	218
New	90	6	15	10	31	121
STORAGE AND DISTRIBUTION						
Typical	185	8	25	10	43	228
Improved	135	7	12	10	29	164
New	80	5	5	10	20	100

Table 3 Building-related energy consumption (see figure 4)

	Building-related energy (£/m² per year)					
	Heating and hot water (fossil)	Fans, pumps, controls (electricity)	Lighting (electricity)	Other (electricity)	Total electricity	Total
GENERAL MANUFACTURING						
Typical	£4.23	£1.60	£3.60	£1.60	£6.80	£11.03
Improved	£2.93	£1.20	£2.40	£1.60	£5.20	£8.13
New	£1.63	£0.80	£1.60	£1.60	£4.00	£5.63
FACTORY-OFFICE						
Typical	£2.93	£1.20	£4.80	£2.00	£8.00	£10.93
Improved	£1.95	£0.96	£2.80	£2.00	£5.76	£7.71
New	£1.30	£0.80	£1.60	£2.00	£4.40	£5.70
LIGHT MANUFACTURING						
Typical	£3.90	£0.80	£4.00	£0.80	£5.60	£9.50
Improved	£2.28	£0.64	£2.00	£0.80	£3.44	£5.72
New	£1.17	£0.48	£1.20	£0.80	£2.48	£3.65
STORAGE AND DISTRIBUTION						
Typical	£2.41	£0.64	£2.00	£0.80	£3.44	£5.85
Improved	£1.76	£0.56	£0.96	£0.80	£2.32	£4.08
New	£1.04	£0.40	£0.40	£0.80	£1.60	£2.64

Table 4 Building-related energy costs – Fossil fuel 1.3p/kWh, Electricity 8p/kWh (see figure 5)

BEST PRACTICE PROGRAMME

Publications available from:

BRECSU

Good Practice Case Studies

- Advance factory units series
- Mixed use business space series
- Offices series

Energy Consumption Guides

10 &19 Energy use in offices

Good Practice Guides

61 Advance factory units: Design Manual (150 pp)
62 Advance factory units: Occupiers' Manual (70 pp)
16 Condensing boilers in commercial buildings
27 & 28 Energy audit and survey guide
33,35 & 46 Energy options in offices
71 Selecting air conditioning systems

General Information Leaflets

1 Condensing boilers in non-domestic buildings
6 Energy efficiency in lighting

General Information Reports

12 Organisational aspects of energy management
13 Reviewing energy management
14 Energy management of buildings including a review of some case studies

CEC Thermie Maxibrochure

- Energy efficient lighting in industrial buildings

Expanded Project Profiles

173 Low energy factory development
202 External insulation on a factory roof
334 Insulated factory doors

A full publication list is available on request.

BRECSU
Tel 0923 664258
Fax 0923 664787

ETSU
Tel 0235 436747
Fax 0235 432923

ETSU

Good Practice Case Studies

- Energy management, training, monitoring and targeting

Good Practice Guides

2 Electric motor and drive systems
13 Heat recovery from high temperature waste gas
14 Retrofitting AC variable speed drives
18 Reducing energy costs by steam metering
30 Energy efficient operation of industrial boiler plant
43 Large scale combined heat and power
1&3 Small scale combined heat and power

New Practice Final Profile

5 Heat recovery in a plastics moulding plant

Expanded Project Profiles

28 Waste heat recovery for space heating
77 Heat recovery in a bakery

A full publication list is available on request.

Some industry sector specific ETSU publications contain information on buildings.

'MAKING A CORPORATE COMMITMENT' CAMPAIGN

- Chairman's check list
- Executive action plan

Telephone 071 276 4613 for campaign material.

EEO PUBLICATIONS

Fuel efficiency booklets

1 Energy audits for industry
1 Energy audits for buildings
2 Steam
3 Economic use of fired space heaters
4 Compressed air and energy use
7 Degree Days
8 The economic thickness of insulation for hot pipes
9 Economic use of electricity in industry
9 Economic use of electricity in buildings
10 Controls and energy savings
11 The economic use of refrigeration plant
12 Energy management and good lighting practices
14 Economic use of oil-fired boiler plant
15 Economic use of gas-fired boiler plant
16 Economic thickness of insulation for existing industrial buildings
17 Economic use of coal-fired boiler plant
19 Process plant insulation and fuel efficiency
20 Energy efficiency in road transport

EEO VIDEOS

The EEO has produced a series of 15 minute videos, 'Managing Energy' covering a range of topics including heating, boilers, ventilation, insulation, metering, lighting, energy awareness and training.

Contact the EEO on 071 276 6200.

REGIONAL ENERGY EFFICIENCY OFFICERS (REEOs)

The REEOs provide a local point of contact, source of information and support.

Scotland (Edinburgh)	031 244 1200
Wales (Cardiff)	0222 823126
Northern (Newcastle upon Tyne)	091 201 3343
Yorkshire and Humberside (Leeds)	0532 438232
North West (Manchester)	061 838 5335
East Midlands (Nottingham)	0602 352292
West Midlands (Birmingham)	021 626 2222
Eastern (Bedford)	0234 276194
South West (Bristol)	0272 218665
South East (London)	071 605 9160
Northern Ireland (Belfast)	0232 529900

ENERGY MANAGEMENT ASSISTANCE SCHEME (EMAS)

EMAS provides help with the cost of consultancy to identify and manage energy efficiency projects, for businesses with fewer than 500 employees. For information, and a booklet on selecting and managing an energy efficiency consultant 'Choosing an energy efficiency consultant',
telephone: 071 276 3755.

ENERGY DESIGN ADVICE SCHEME (EDAS)

EDAS offers support to design teams or clients in the energy aspects of new buildings or refurbishment projects. The scheme pays for an initial one day consultancy to eligible applicants. Further expert consultancy and advice may then be offered, and a proportion of these costs can be reimbursed by the scheme.

Regional Centres are:

Scotland	031 229 7545
South East	071 916 3891
N. Ireland	0232 364090
N. England	0742 721140

LOCAL ENERGY ADVICE CENTRES

Smaller businesses can obtain free independent advice from Local Energy Advice Centres in the UK. For further details contact the Energy Savings Trust,
telephone: 071 931 8401.

BUILDING RESEARCH ESTABLISHMENT ENVIRONMENTAL ASSESSMENT METHOD (BREEAM)

Version 1/93 New office designs
Version 2/91 New superstores and supermarkets
Version 4/93 Existing office buildings
Version 5/93 New industrial, warehousing and non-food retail units

To order BREEAM publications,
telephone: 0923 664444.

To submit a building design for assessment write to: BREEAM Project Manager, Building Research Establishment, Garston, Watford WD2 7JR.

CIBSE PUBLICATIONS

AM3: Condensing boilers, 1989
AM5: Energy audits and surveys, 1991.
AM6: Contract energy management 1991
LG1: Lighting Guide - The industrial environment, 1989.
CIBSE Code for Interior Lighting, 1993.

The above are available from the Chartered Institution of Building Services Engineers. Delta House, 222 Balham High Road, London SW12 9BS.

ENERGY SYSTEMS TRADE ASSOCIATION (ESTA)

This is a trade association of suppliers of services and equipment for improving energy efficiency (including energy consultants, heating, ventilation and air conditioning, boilers, lighting, control equipment, metering and monitoring, building energy management systems, contract energy management, CHP and heat recovery). Telephone 0453 873568.

For further copies of this or other Best Practice programme publications please contact BRECSU and ETSU.
For buildings-related projects: Enquiries Bureau, BRECSU, Building Research Establishment, Garston, Watford, WD2 7JR. Tel 0923 664258. Fax 0923 664787.
For industrial projects: Energy Efficiency Enquiries Bureau, ETSU, Harwell, Oxfordshire OX11 0RA. Tel 0235 436747. Telex 83135. Fax 0235 432923.